PIEZOELECTRIC ACTUATOR AND ITS MANUFACTURING METHOD

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Inventor: SAEKI KIYOSHI; IDOGAKI KOJI
Applicant: DENSO CORP
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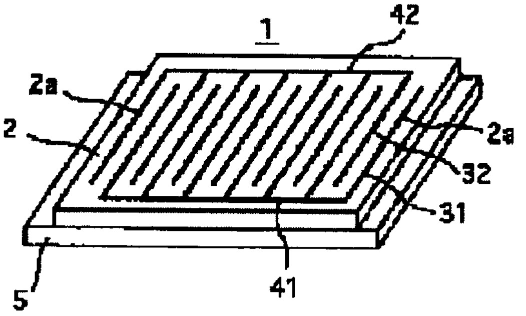
Abstract of **JP10144974**

PROBLEM TO BE SOLVED: To provide a piezoelectric actuator that is a face deformation element for obtaining a sufficient generation force or a displacement, while operating at a low voltage and its manufacturing method. SOLUTION: A piezoelectric actuator 1 has an elastic plate 5 that is a thin plate with spring elasticity, a piezoelectric plate 2 that is a thin plate made of a piezoelectric material being jointed onto the surface of the elastic plate 5, and a first electrode 31 and a second electrode 32 that are accommodated in a plurality of grooves 2a formed at the piezoelectric plate 2 with a gap that is equal to or less than the thickness of the piezoelectric plate 2 and are adjacent, while sandwiching a piezoelectric material. The piezoelectric actuator 1 can generate a sufficiently high electric field, even if an applied voltage is small, since the gap between both electrodes 31 and 32 is narrow and can utilize a piezoelectric constant d33 that is approximately two times larger than a piezoelectric constant d33 , so that it can achieve a larger occurrence force and the maximum displacement even at a low voltage.



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(71)出願人　000004260
株式会社デンソー
愛知県刈谷市昭和町１丁目１番地

(72)発明者　佐伯　清
愛知県刈谷市昭和町１丁目１番地　株式会社デンソー内

(72)発明者　井戸垣　孝治
愛知県刈谷市昭和町１丁目１番地　株式会社デンソー内

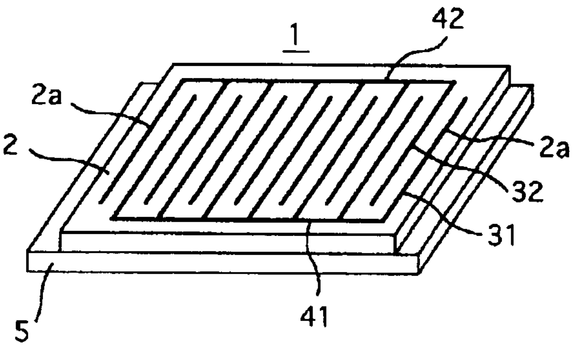
(74)代理人　弁理士　大川　宏

(54)【発明の名称】　圧電アクチュエータおよびその製造方法

(57)【要約】

【課題】　低電圧で作動しながら十分な発生力または変位を得ることができる面変形素子である圧電アクチュエータと、その製造方法とを提供すること。

【解決手段】　本発明の圧電アクチュエータ１は、バネ弾性を持つ薄板である弾性板５と、弾性板５の表面に接合されている圧電材料からなる薄板である圧電板２と、圧電板２の厚さ以下の間隔で圧電板２に形成されている複数の溝２ａの中に収容されており圧電材料を挟んで隣接している第１電極３１および第２電極３２とを有する。本圧電アクチュエータ１は、両電極３１，３２の間隔が狭いので印加電圧が低くても十分に高い電界が生じ、そのうえ圧電定数d_{31}の倍程度の圧電定数d_{33}を利用できるので、低電圧でもより大きな発生力および最大変位を発揮できる。



【特許請求の範囲】

【請求項１】バネ弾性を持つ薄板である弾性板と、
該弾性板の少なくとも一方の表面に接合されている圧電材料からなる薄板である圧電板と、
該圧電板の厚さ以下の間隔で該圧電板に形成されている複数の溝の中に導電材が充填されており、互いに該圧電材料を挟んで隣接している該導電材から形成されている第１電極および第２電極と、を有することを特徴とする、圧電アクチュエータ。

【請求項２】前記第１電極および前記第２電極を収容している前記溝は、前記圧電板の前記弾性板と背向する表面に開口している、請求項１記載の圧電アクチュエータ。

【請求項３】前記第１電極および前記第２電極は、前記圧電板の厚さ方向の面内に互いに対向する二つの櫛の歯状に交互に配設されている、請求項１記載の圧電アクチュエータ。

【請求項４】前記第１電極および前記第２電極は、前記圧電板の表面に平行な面内に互いに対向する二つの櫛の歯状に交互に配設されている、請求項１記載の圧電アクチュエータ。

【請求項５】前記第１電極および前記第２電極は、前記圧電板の表面に平行な面内に、直線状、屈折した直線状、円弧状および二重螺旋状を含む曲線状、およびこれらが複合している形状のうちいずれかの形状で配設されている、請求項１記載の圧電アクチュエータ。

【請求項６】前記圧電板は複数の区画に区切られており、該各区画についてそれぞれ対をなす複数の前記第１電極および前記第２電極を有する、請求項１記載の圧電アクチュエータ。

【請求項７】バネ弾性を持つ薄板である弾性板の表面に接合されるまたは接合されている圧電材料からなる薄板である圧電板の表面から、該圧電板の厚さよりも短い間隔で複数の溝を該圧電板に形成する溝形成工程と、
該溝の中に導電材を充填して、互いに該圧電材料を挟んで隣接している第１電極および第２電極を形成する電極形成工程と、
該第１電極と該第２電極との間に高電圧を印加して、該両電極の間に挟まれている該圧電材料を分極させる分極工程と、を有することを特徴とする、圧電アクチュエータの製造方法。

【請求項８】前記溝形成工程は、ダイシング加工、レーザ加工および反応性イオンエッチング加工のうちいずれかにより前記溝を形成する工程である、請求項７記載の圧電アクチュエータの製造方法。

【請求項９】前記電極形成工程は、ＣＶＤ、スパッタリング、導電性ペーストの刷り込み、無電解メッキおよび蒸着のうちいずれかにより、前記第１電極および前記第２電極を形成する工程である、請求項７記載の圧電アクチュエータの製造方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、圧電ユニモルフや圧電バイモルフに類する面変形素子である圧電アクチュエータの技術分野に属する。

【０００２】

【従来の技術】従来技術の面変形素子である圧電アクチュエータとしては、圧電ユニモルフや圧電バイモルフがある。これらは通常、バネ弾性を持つ薄板である弾性板と、この弾性板の少なくとも一方の表面に接合されている圧電材料からなる薄板である圧電板と、各圧電板の両面にそれぞれ形成ないし接合されている一対の電極とから構成されている。

【０００３】上記一対の電極に電圧が印加されると、印加電圧を厚さで割った電界強度の電界が圧電板の厚さ方向に生じ、電界強度と圧電定数d_{31}との積に比例して圧電板は厚さ方向と垂直な面内変位（または面内変位を起こそうとする圧力）を生じる。その結果、ユニモルフやバイモルフなどの面変形素子は、一方に反るかまたは反ろうとする力を発生する。

【０００４】一例として圧電ユニモルフＰ１を取り上げると、図１２に示すように金属製の円盤状弾性板Ｐ５の片面に圧電板Ｐ２が接合されており、図１３（ａ）に示すように圧電板Ｐ２の両面にそれぞれ電極Ｐ３が形成されている。上記両電極Ｐ３に電圧を印加すると、図１３（ｂ）に示すように、分極方向とは直交する面内方向に圧電板Ｐ２が収縮し、ユニモルフＰ１全体が反って変形する。この際、圧電板Ｐ２の変形圧力（固定時の応力）は、印加電圧を圧電板Ｐ２の厚さで割った電界強度と圧電定数d_{31}とに比例する。

【０００５】

【発明が解決しようとする課題】前述のユニモルフやバイモルフでは、低電圧で作動させるためには、圧電板の厚さを薄く形成して低電圧でも十分に強い電界強度が得られるようにする手段がある。ところが、圧電板の厚さを薄くすると面内方向の断面積が小さくなるので面内方向に発生する力が弱くなり、十分な発生力を得ることができない。それゆえ前述の従来技術によっては、低電圧で作動しながら十分な発生力と変位とを得ることができない。

【０００６】そこで本発明は、低電圧で作動しながら十分な発生力および変位のうち少なくとも一方を得ることができる面変形素子である圧電アクチュエータとその製造方法とを提供することを解決すべき課題とする。

【０００７】

【課題を解決するための手段およびその作用・効果】上記課題を解決するために、発明者らは以下の手段を発明した。

［圧電アクチュエータ］

（第１手段）本発明の第１手段は、請求項１記載の圧電

アクチュエータである。圧電板には製造過程で第１電極と第２電極との間に高電圧がかけられており、面内方向の各電極面と直交する向きに圧電材料の分極が予め形成されている。

【０００８】ここで、弾性板を形成している材料は、ステンレス鋼、銅および銅合金などの金属等、導電性の材料でも、合成樹脂および、ガラスなどの絶縁性の材料でも、あるいはシリコンなどの半導体材料でも良い。また、圧電板を形成している材料は、電圧の印加により圧電効果または逆圧電効果を生じる圧電材料の中から適宜選択することができ、例えば圧電セラミックスのＰＺＴ（ジルコン酸チタン酸鉛）を採用することができる。一方、各電極を形成している材料は、導電性の材料の中から適宜選択することができ、例えばアルミニウム、金、銀、白金、タングステン、銅およびこれらの合金などの金属を採用することができる。

【０００９】本手段では、圧電板の厚さ以下の間隔で形成されている複数の溝の中に導電材が充填されて、互いに該圧電材料を挟んで隣接して第１電極および第２電極が形成されている。それゆえ、上記両電極間に電圧が印加されると、面内方向に電界が発生し、電界強度と圧電定数d_{33}との積に比例して圧電板は厚さ方向と垂直な面内方向（電界と平行な方向）に伸縮変位または伸縮力を生じる。ここで、溝の間隔すなわち両電極の間隔が狭いほど低電圧でも強電界が発生するのであり、電界強度は圧電板の厚さには左右されないので、十分な変形力を発揮できるだけの厚さを圧電板に与えることができる。

【００１０】この際、互いに隣接する両電極の間隔が圧電板の厚さに対して十分に小さければ、印加する電圧が低電圧であっても十分に高い電界強度が面内方向に生じ、本手段の圧電アクチュエータには十分な曲げ変形または曲げ力を発生する。また、圧電定数d_{31}を利用していた従来技術と異なり、圧電定数d_{33}により面内方向の伸縮変形または伸縮力が発生する。ここで、圧電定数d_{33}は、圧電定数d_{31}に比べて通常２倍程度大きいので、電界強度が同じであれば、本手段の圧電アクチュエータが発生する変形力は従来技術に比べて２倍程度大きくなる。この効果は両電極の間隔が圧電板の厚みと同程度である場合にも発揮され、同じ電界強度であっても約２倍の伸縮力が得られる。

【００１１】また、溝の幅すなわち両電極の幅が両電極の間隔よりも通常は小さいので、本手段の変位の大きさも従来技術のそれよりも大きくなる。しかも、本手段の圧電アクチュエータで従来技術と同等の変位（電界強度と圧電定数d_{33}との積に比例）を得るためには、印加する電圧は本手段の方が従来技術よりも低くて済む。したがって本手段によれば、従来技術よりもずっと低い印加電圧で圧電アクチュエータを作動させることができ、その変形力および変形量も従来技術より大きくなるという効果がある。

【００１２】（第２手段）本発明の第２手段は、請求項２記載の圧電アクチュエータである。本手段では、両電極を収容しているそれぞれの溝が、圧電板の表面に開口しているので、弾性板に接合されている圧電板の表面から、微細加工技術を駆使して精密に溝を形成することが可能である。また、同一の表面からの加工で溝が形成されるので、第１電極の溝と第２電極の溝との精密な位置合わせが容易にでき、両溝の間隔を精密に一定に保って加工することが容易になる。さらに、両電極を圧電板の一方の面から一度に形成することが可能であり、圧電板の両面に各電極の溝がそれぞれ開口している場合と比較して、両電極を形成する工程も簡易化される。加えて、圧電板を弾性板に接合してから溝を形成することができるので、溝が形成されている圧電板に割れが生じにくくなり、製造中の取り扱いも容易になる。

【００１３】したがって本手段によれば、前述の第１手段の効果に加えて、本発明の圧電アクチュエータの製造が容易になるという効果がある。なお、弾性板が金属等の導電性の材料からなる場合には、溝の深さは両電極と弾性板との間で絶縁が保たれる範囲で留められるが、弾性板が合成樹脂やガラスなどの絶縁性材料からなるである場合には、溝は弾性板を貫通していても良い。後者の場合には、圧電板が弾性板に接合されたうえで溝が形成されることになるが、前者の場合よりもより広く（深く）圧電板に電界をかけることができるので、発生力および変形量は前者よりも増大する。

【００１４】（第３手段）本発明の第３手段は、請求項３記載の圧電アクチュエータである。本手段では、両電極のうち一方は弾性板に対向する圧電板の接合面に開口している溝の中に形成されており、他方は弾性板に背向する圧電板の表面に開口している溝の中に形成されている。すなわち、両電極は圧電板の表裏から交互に形成されている。それゆえ、一方の面を一方の電極との接続面とし、他方の面を他方の電極への接続面とすることができるので、両電極と駆動電源との接続が容易になり、同一面で短絡するおそれが無くなる。

【００１５】したがって本手段によれば、前述の第１手段の効果に加えて、両電極と駆動電源との接続が容易になるばかりではなく、両電極間での短絡が防止されるという効果がある。

（第４手段）本発明の第４手段は、請求項４記載の圧電アクチュエータである。

【００１６】本手段では、両電極の圧電板上のパターンがそれぞれ直線でのみ形成されており、圧電板の表面の面積に対して最も密に両電極を配設することができるので、印加電圧が低くても大きな発生力を得ることができる。また圧電アクチュエータは、従来技術のように略球面状に反るのではなくて一方向に反り、一次曲面を形成する。

【００１７】したがって本手段によれば、前述の第１手

段の効果に加えて、より低い印加電圧で十分に大きな変位ないし発生力が得られるうえ、圧電アクチュエータが一次曲面に変形するという効果がある。

（第５手段）本発明の第５手段は、請求項５記載の圧電アクチュエータである。

【００１８】本手段では、両電極は、直線や曲線を含む任意のパターンで圧電板に形成されるので、圧電アクチュエータを一次曲面にも正負いずれの二次曲面にも変形させることができる。したがって本手段によれば、前述の第１手段の効果に加えて、圧電アクチュエータの変形形状や変形しようとする方向を任意に設計することができるという効果がある。

【００１９】（第６手段）本発明の第６手段は、請求項６記載の圧電アクチュエータである。本手段では、各区画毎に印加電圧を互いに独立して制御することができるので、各区画毎に変形の方向と変形量とを個別に与えることが可能であり、圧電アクチュエータを複雑な形状に変形させることが可能になる。

【００２０】したがって本手段によれば、前述の第１手段の効果に加えて、各区画毎に変形を個別に制御することができ、圧電アクチュエータを複雑な形状に変形させることが可能になるという効果がある。

［圧電アクチュエータの製造方法］

（第７手段）本発明の第７手段は、請求項７記載の圧電アクチュエータである。

【００２１】本手段では少なくとも、圧電材料からなる薄板である圧電板の表面から該圧電板の厚さよりも短い間隔で複数の溝を該圧電板に形成する溝形成工程と、この溝の中に導電材を充填して第１電極および第２電極を形成する電極形成工程と、両電極の間に高電圧を印加して圧電材料を分極させる分極工程とにより、第１手段の圧電アクチュエータが製造される。溝形成工程には半導体の微細加工技術の転用が可能で容易に溝を形成することができ、また電極形成工程にも各工学分野で成熟している加工技術を転用することができる。また分極工程も、通常の圧電素子で行われている工程と基本的には同一であり、本手段の製造方法には技術的な難関はない。

【００２２】したがって本手段によれば、すでに成熟している加工技術の転用で容易に前述の第１手段の圧電アクチュエータを製造することができるという効果がある。

（第８手段）本発明の第８手段は、請求項８記載の圧電アクチュエータの製造方法である。本手段では、溝形成工程に、ダイシング加工、レーザ加工および反応性イオンエッチング加工のうちいずれかの加工技術が使用される。ダイシング加工には、安価で簡便な加工設備で済み、加工が速やかに行われるという利点がある。一方、レーザ加工および反応性イオンエッチング加工には、圧電板の表面上の溝のパターンを曲線も含めて任意に設計できるという利点がある。

【００２３】（第９手段）本発明の第９手段は、請求項９記載の圧電アクチュエータの製造方法である。本手段では、電極形成工程に、ＣＶＤ（化学的気相成長法）、スパッタリング、導電性ペーストの刷り込み、無電解メッキおよび蒸着のうちいずれかの加工技術が使用される。ＣＶＤ、蒸着およびスパッタリングには、比較的緻密に両電極が形成されるうえ、一度に複数枚の電極形成が可能になるという利点がある。一方、導電性ペーストの刷り込みおよび無電解メッキには、安価で簡便な加工設備で済むうえ、加工時間が比較的短くて済むという利点がある。

【００２４】なお、溝形成工程で圧電板の表面にマスク材が接合されている場合には、同マスク材を電極形成工程でも使用したうえで電極形成工程の終了後に除去すれば、同マスク材と共に余分な導電材が除去されるので合理的である。逆に溝形成工程で圧電板の表面にマスク材が接合されていない場合には、圧電板の表面に堆積した余分な導電材は、研削等の機械加工で除去しても良い。

【００２５】

【発明の実施の形態】本発明の圧電アクチュエータおよびその製造方法の実施の形態については、当業者に実施可能な理解が得らえるように、以下の実施例で明確かつ十分に説明する。

［実施例１］

（実施例１の構成）本実施例の圧電アクチュエータ１は、図１に示すように、平面形が矩形の形状をしている。すなわち圧電アクチュエータ１は、矩形の弾性板５と、その一方の表面にエポキシ系接着剤で接合されている矩形の圧電板２と、圧電板２に形成されている溝２ａ内に収容されている各電極３１，３２，４１，４２とから構成されている。

【００２６】弾性板５は、バネ弾性を持つ薄板であり、幅１０ｍｍ、奥行き１５ｍｍ、厚さ０．０５ｍｍのステンレス鋼の平板である。圧電板２は、ＰＺＴ圧電材料からなる薄板であり、幅８ｍｍ、奥行き１２ｍｍ、厚さ０．０５ｍｍの平板である。圧電板２には、溝２ａが、表面に平行な面内に互いに対向する二つの櫛の歯状に交互に形成されている。一方の櫛の歯状の溝２ａの中には導電材が充填されて第１電極３１を形成しており、他方の櫛の歯状の溝２ａの中には同じ導電材が充填されて第２電極３２を形成している。第１電極３１と第２電極３２とは、圧電板２の圧電材料を挟んで互いに絶縁されている。全ての第１電極３１は、その一端で同じく導電材で溝２ａ内に形成されている第１共通電極４１と接続しており、同様に全ての第２電極３２は、その一端で同じく導電材で溝２ａ内に形成されている第２共通電極４２と接続している。上記導電材はアルミニウムであるが、金やタングステンなどに適宜変更することも可能である。

【００２７】図２に示すように、全ての溝２ａは弾性板

５に背向している圧電板２の表面に開口しており、この開口部から溝２ａ内に導電材が導入されて各電極３１，３２，４１，４２が形成されている。なお、第１共通電極４１および第２共通電極４２は、それぞれボンディングワイヤまたはリード線に接続されて、駆動電源（図略）からの印加電圧を受けられるようになっている。

【００２８】上記各電極３１，３２，４１，４２は、深さ０．０４５mm（圧電板２の厚さの９０％）、幅０．０１５mmで形成されており、第１電極３１と第２電極３２との間隔は一定で０．０３mm（圧電板２の厚さの３／５）である。すなわち図３に示すように、この電極間の間隔に相当する厚さで、第１電極３１と第２電極３２との間に両電極の表面と垂直な方向に分極している圧電材料が挟持されている。

【００２９】（実施例１の作用効果）本実施例の圧電アクチュエータ１は、電圧が印加されていない状態では、図４（ａ）に示すように、全体として平板状をしている。一方、図４（ｂ）に示すように、スイッチ６が閉じて駆動電源としての電池７から電圧が印加されている状態では、両電極３１，３２が交互に積層されている方向（電界と平行な方向）に圧電材料は伸張する。この際、伸張率は圧電板２の圧電定数d_{33}（定数）と電池７の印加電圧による電界強度との積に（印加電圧が所定の範囲では）比例する。この電界強度は、印加電圧を各電極３１，３２の間隔で割った値であるから、前述のように圧電板２の厚さよりも上記間隔がずっと狭い本実施例の圧電アクチュエータ１では、低い印加電圧であっても十分に大きな電界強度が生じる。また、圧電板２の厚さも、弾性板５を曲げるのに十分な曲げモーメントを生じるだけの厚さが確保されている。

【００３０】その結果、圧電板２は十分に大きな伸張力を生じ、所定量だけ各電極３１，３２の積層方向に伸張して、弾性板５を所定の曲率で曲げる（圧電板２も弾性板５に接合したまま曲がる）。この曲げ変形により、本実施例の圧電アクチュエータ１は全体として一次曲面を形成する。以上詳述したように、本実施例の圧電アクチュエータ１によれば、印加電圧が比較的低くても、十分な曲げ変形力を生じ、その結果十分に大きな曲げ変形量を発生させることができるという効果がある。

【００３１】（実施例１の応用）本実施例の圧電アクチュエータ１をマイクロマシンに採用した場合、駆動に必要とされる印加電圧が比較的低電圧であるので、高電圧発生装置を要せずマイクロマシンに搭載した電池で圧電アクチュエータ１を駆動することができる。したがって、マイクロマシンを給電ケーブルなしに単体として構成することが容易になるという効果がある。また、高電圧を必要としないので、短絡の防止も容易であり、その分、マイクロマシンを小型軽量化できるとの効果もある。

【００３２】（実施例１の変形態様）前述の実施例１の圧電アクチュエータ１において、弾性板５を絶縁性のガラスないし合成樹脂で形成し、圧電板２を貫通して溝２ａを形成して両電極３１，３２を圧電板２の厚さの全体に渡って形成する変形態様も実施可能である。本変形態様によれば、より大きな発生力および変形量が得られるという効果がある。

【００３３】なお、共通電極４１，４２は、導電路として機能しているだけなので、圧電板２の厚さの全体に渡って形成されている必要はない。さらに、実施例１でも同様であるが、共通電極４１，４２は電極３１，３２よりも広い幅で形成されていることが、電極３１，３２および電極パッドＰとの導通を確保するうえで望ましい。

【００３４】また、実施例１やその変形態様と同様の構成で、弾性板５の表裏両面にそれぞれ圧電板２が接合されているバイモルフのような変形態様も実施可能である。

（実施例１の製造方法）本実施例の圧電アクチュエータ１の製造方法は、接合工程、溝形成工程、電極形成工程および分極工程の順に構成されている。

【００３５】接合工程は、所定の寸法の薄板に成形されている弾性板５および圧電板２を用意し、互いの方位を合わせて圧電板２を弾性板５の一方の表面に接着剤で接合固定する工程である。本工程では、次の溝形成工程に移る前に、接着剤を十分に硬化させて圧電板２と弾性板５との接合を完全にしておく。ここで、圧電アクチュエータ１を構成する所定の寸法に弾性板５および圧電板２が裁断される以前に両者５，２を互いに接合しておき、全ての工程が完了した後に上記所定の寸法に裁断する製造方法も取りうる。この方法によれば、多くの半導体チップと同様に、多数の圧電アクチュエータ１を一度に製造することが可能である。

【００３６】溝形成工程は、弾性板５の表面に接合されている圧電板２の表面から、圧電板２の厚さよりも短い間隔で複数の溝２ａを前述のパターン（図１参照）で圧電板２に形成する工程である。本実施例では、溝２ａのパターンが全て直線の線分から構成されているので、溝形成工程にダイシング加工が使用され、機械的に切削されて所定の深さの溝２ａが形成されている。

【００３７】電極形成工程は、溝２ａの中に導電材を充填して、圧電板２の圧電材料を挟んで互いに隣接している第１電極３１および第２電極３２を形成する工程である。本実施例では、微量の溶剤中に銀の微粉末を多量に含む導電性ペーストを全ての溝２ａにローラーで刷り込む加工方法が取られている。刷り込みの際、ローラーは溝２ａに対して斜めの方向から往復し、上記ペーストを全ての溝２ａに完全に充填する。ここで、減圧された雰囲気中で上記刷り込みを行うと、溝２ａの奥に気泡（ボイド）が残りにくいので、より望ましい。なお、圧電板２の表面に付着した余分な導電性ペーストは、ローラーによる刷り込み後、溶剤で拭き取ればきれいに除去され

て短絡の心配はなくなる。

【００３８】溝２ａに充填された上記ペーストから溶剤が蒸発した後、圧電板２を弾性板５と共に熱処理炉に入れ、適正な温度にまで昇温して銀の微粉末を溶解させて銀の電極３１，３２，４１，４２を焼成する。すなわち、熱処理後に冷却されて銀が溝２ａの中で連続して固まり、各電極３１，３２，４１，４２が形成される。電極形成工程で各電極３１，３２，４１，４２が形成されたのち、第１電極３１および第１共通電極４１のうちいずれかに一本、第２電極３２および第２共通電極４２のうちいずれかに他の一本のリード線を接合する。本実施例の場合は、図５に示すように、最も圧電板２の辺縁部に近い第１電極３１の端部および第２電極３２の端部に、銀を主成分とする導電性ペーストが印刷されて焼成され、それぞれの電極パッドＰが形成されている。そして、各電極パッドＰには、それぞれリード線Ｌが半田付けで接続されている（導電性接着剤による接着でも良い）。

【００３９】最後に分極工程では、各リード線Ｌを介して第１電極３１と第２電極３２との間に高電圧を印加し、両電極３１，３２間に挟まれている圧電板２の圧電材料を分極させる。以上の本実施例の製造方法により、本実施例の圧電アクチュエータが製造される。本実施例の製造方法によれば、製造に要する設備が安価かつ簡便であり、試作品などの少量生産では特に素早く安価に前述の圧電アクチュエータを製造することができるという効果がある。

【００４０】（実施例１の製造方法の変形態様１）本実施例の製造方法の変形態様として、実施例１と同様の接合工程の後、溝形成工程にレーザ加工法を使用し、電極形成工程にＣＶＤを使用する製造方法が可能である。レーザ加工法による溝形成工程では、図６に示すように、波長が１μｍ程度の赤外線レーザ光１０を集光レンズ１１で集光し、純水９に浸されている圧電板２の溝２ａを形成すべき部位に照射する。すると、赤外レーザ光の集中照射による局部的な温度上昇により、圧電板２を形成しているＰＺＴは被照射部位で純水９と化学反応して浸食され、溝２ａが徐々に形成される。圧電板２上の溝２ａを形成すべきパターンに沿ってレーザ光１０を走査させることにより、各電極３１，３２，４１，４２を収容すべき溝２ａが全て形成される。

【００４１】ＣＶＤによる電極形成工程では、溝２ａ以外の圧電板２の表面にはレジストでマスクを形成しておき、溝２ａ内に導電物質（本実施例では銀）が付着するようにパターニングしておく。その結果、溝２ａ内には各電極３１，３２，４１，４２が形成され、その他の圧電板２の表面は清浄に保たれる。なお、マスク材によるパターニングをしないで、圧電板２の表面に堆積した導電物質を、切削や研摩等の機械加工や化学処理で除去してしまっても良い。

【００４２】リード線Ｌに代わるボンディングワイヤを接続すべき電極パッドＰは、上記電極形成工程で溝２ａと同時に形成される。本変形態様の製造方法の長所は、機械加工によらずレーザ加工で溝２ａを形成するので、より細い幅の溝２ａをより狭い間隔で形成できることで、それゆえ、より低電圧で作動が可能になるという効果がある。ちなみに溝２ａ幅の最小限度は、赤外線レーザで５μｍ程度、紫外線レーザで２μｍ程度であり、溝２ａの間隔の最小限度は、赤外線レーザで３０μｍ程度、紫外線レーザで１０μｍ程度である。

【００４３】（実施例１の製造方法の変形態様２）本実施例の製造方法の変形態様として、実施例１と同様の接合工程の後、溝形成工程に反応性イオンエッチングを使用し、電極形成工程にスパッタリングを使用する製造方法が可能である。反応性イオンエッチングによる溝形成工程では、図７に示すように、反応性イオンエッチング装置の加工用真空チャンバ１３内に、レジストのマスク材で表面がパターニングされている圧電板２を入れて加工する。同装置では、高周波の交流電源１５により駆動される磁場コイル１４による交流磁場内に、反応性ガスのプラズマ１７が発生し、圧電板２の溝２ａを形成すべき部位で化学反応による浸食が起こる。この際、反応性ガスとしては、CF_4，Cl_2 等を使用することができる。一方、弾性板５に接合されている圧電板２は、電極基板１２上に複数個が並べられており、電極基板１２を介して高周波の交流電源１５から高電圧を印加されている。なお、加工用真空チャンバは、真空排気系１６により適正な真空度に保たれている。

【００４４】スパッタリングによる電極形成工程では、溝２ａ以外の圧電板２の表面には上記溝形成工程で使用したマスクを残しておき、スパッタリングで溝２ａ内に導電物質を付着させる。その結果、溝２ａ内には各電極３１，３２，４１，４２が形成され、その他の圧電板２の表面はマスクを剥がすと清浄に保たれている。リード線Ｌに代わるボンディングワイヤを接続すべき電極パッドＰは、上記電極形成工程で溝２ａと同時に形成される。

【００４５】本変形態様の製造方法の長所は、反応性イオンエッチングとスパッタリングとを使用して溝２ａと各電極３１，３２，４１，４２とを形成するので、一度に沢山の圧電板２を加工することができ、大量生産が容易になることである。

（実施例１の電極パッドの形成）電極パッドＰは、ＣＶＤ、スパッタリング、蒸着または無電解メッキによるアルミニウム、銀、金またはニッケル等の成膜で形成が可能である。それゆえ、前述のように、電極３１，３２，４１，４２をこれらの加工法で形成する際に、同時に形成するのが合理的である。成膜の電極パッドＰには、ワイヤボンディングにより電圧源との接続が可能である。

【００４６】（実施例１の変形態様）前述の実施例１の

圧電アクチュエータ１では、ユニモルフと同様に弾性板５の片面にしか圧電板２が接合されていなかったが、バイモルフと同様に弾性板５の両面に圧電板２がそれぞれ接合されている変形態様も可能である。本変形態様の圧電アクチュエータによれば、前述の圧電アクチュエータ１に比べ発生力を倍増できるという効果がある。

【００４７】［実施例２］

（実施例２の構成）本発明の実施例２としての圧電アクチュエータ１’は、図８および図９に示すように、一枚の円盤状のステンレス鋼製の薄板からなる円盤状の弾性板５’と、弾性板５の表裏両面に導電性接着剤でそれぞれ接合されている二枚の圧電板２’とからなる。圧電板２は、実施例１と同様にＰＺＴからなる薄板で、弾性板５よりやや直径が小さな円盤状をしている。

【００４８】二枚の圧電板２’は、図８に示すように二つの区画に区切られており、この二つの区画は、二枚の圧電板２’について表裏で対応している。圧電板２’は、各区画についてそれぞれ対をなす複数の第１電極３１’および第２電極３２’を有している。また各圧電板２は、各区画でそれぞれ各第１電極３１’を接続している第１共通電極４１’と、それぞれ各第２電極３２’を接続している第２共通電極４２とを有する。

【００４９】複数の第１電極３１’はそれぞれ略半円弧状のパターンを圧電板２’の表面に描いて形成されており、二つの第１共通電極４１’も圧電板２’の表面にそれぞれ直線状にパターンを描いて形成されている。一方、複数の第２電極３２’もそれぞれ略半円弧状のパターンを圧電板２’の裏面（弾性板５’と接合する面）に描いて形成されており、二つの第２共通電極４２’も圧電板２’の裏面にそれぞれ直線状にパターンを描いて形成されている。

【００５０】すなわち、第１電極３１’および第２電極３２’は、図９に示すように、それぞれの圧電板２’の厚さ方向の面内に互いに対向する二つの櫛の歯状に交互に配設されている。第１電極３１’および第１共通電極４１’は、各区画毎に形成された電極パッド（図略）により、それぞれリード線に接続されている。一方、第２電極３２’および第２共通電極４２は、導電性接着剤を介して弾性板５に接続されており、さらに弾性板５を介して他のリード線（図略）に接続されている。それゆえ、第２共通電極４２’の必要性はなく、第２共通電極４２’を省略して構成することも可能である。

【００５１】第１電極３１’と第２電極３２’とに挟まれている圧電材料は、図中上側の圧電板２’では、第２電極３２’から第１電極３１’の方向へ圧電板２’の面内方向で分極している。一方、図中下側の圧電板２’を形成している圧電材料は、逆に第１電極３１’から第２電極３２’の方向へ分極している。

（実施例２の作用効果）本実施例の圧電アクチュエータ１’は、二枚の圧電板２’内に形成されている両電極３１’，３２’が、図１０（ａ）に示すように左右二つの区画に分かれているので、各区画を別個に制御することが可能である。この際、圧電板２’と第２電極３２’および第２共通電極４２’とはアース線８を介して接地している。一方、同図中右半面の区画の表裏の圧電板２’の第１電極３１’は、回路４’に接続されており、さらにスイッチ６を介して正の駆動電源７に導通しうる。他方、同図中左半面の区画の表裏の圧電板２’の第１電極３１’は、他の回路４’に接続されており、さらにスイッチ６’を介して負の駆動電源７’に導通しうる。

【００５２】すなわち、図１０（ｂ）に示すように、スイッチ６を閉じて同図中右側の区画の回路４’にだけ正の電圧を印加すると、圧電アクチュエータ１’は右半面だけが上に凸に曲がり変形する。さらに、図１０（ｃ）に示すように、スイッチ６’を閉じて同図中左側の区画の回路４’にだけ負の電圧を印加すると、圧電アクチュエータ１’の左半面は、下に凸に曲がり変形する。

【００５３】以上詳述したように、本実施例の圧電アクチュエータ１’では対になる電極３１’，３２’が二つの区画に分かれているので、二つの区画をそれぞれ別個に制御することができるという効果がある。また、弾性板５’の両面に圧電板２’が接合されているので、ユニモルフに対するバイモルフと同様に、実施例１のように圧電板２が弾性板５の片側にしかない構成の圧電アクチュエータ１に比べ、発生力を倍加させることができるという効果もある。

【００５４】（実施例２の製造方法）本実施例の圧電アクチュエータ１’は、前述の実施例１の製造方法の変形態様１や変形態様２などの製造方法を圧電板２’の表裏に対して実施することで、製造することができる。各製造方法の特徴や利点の違いも、実施例１の各変形態様と同様である。

【００５５】なお、圧電板２’の表裏の各電極３１’，３２’の位置合わせは、ＬＳＩ等の集積回路の微細加工技術の応用で、容易かつ精密になすことが可能である。

（実施例２の変形態様１）各圧電板２’のそれぞれの表面に区画毎に分けて導電性ペーストを印刷し、焼成して導電性の金属（例えば銀）膜を成膜して各区画全体を覆って、実施例２の電極パッドに代えることが可能である。すなわち本変形態様では、弾性板５’と各区画の導電性の成膜とをそれぞれ共通電極として使用することが可能である。

【００５６】それゆえ本変形態様では、第１共通電極４１’および第２共通電極４２’は不要であり、溝形成工程を簡略化することができる。したがって本変形態様によれば、各区画の導電性の成膜も共通電極として作用するので、実施例１の効果に加えて第１電極３１’の導通不良の可能性が減って信頼性が向上するという効果がある。

【００５７】（実施例２の変形態様２）実施例２では、

圧電板２’を二つの区画に分割して両電極３１’，３２’を配していたが、３つ以上の区画に分割する変形態様も可能であり、また、区画の分割のしかたも同心円状であったりしても良い。例えば、弾性板５’の外周部が剛に固定されている場合には、円盤状の圧電板２’を内周部と外周部との二つに同心円状に区画し、両区画の一方と他方とで逆に印加電圧をかける変形態様も可能である。本変形態様では、内周部と外周部とで逆の曲率を持つので、圧電アクチュエータの発生力および最大変位が共に大きくなるという効果がある。

【００５８】［実施例３］

（実施例３の製造方法）本発明の実施例３としての圧電アクチュエータ１”は、図１１に示すように、弾性板５”の片面（または両面）に接合されている圧電板２”に、表面に二重螺旋のパターンを描いて第１電極３１”および第２電極３２”が形成されている。弾性板５”は、ガラス等の絶縁性材料からなる円盤状の薄板であり、この弾性板５”の厚さのほぼ全体に渡って上記電極３１”，３２”を収容している溝が形成されている。第１電極３１”と第２電極３２”とは、ごく狭い所定の間隔を空けて互いに隣接して形成されており、両電極３１”，３２”の一端は、それぞれ円盤状の圧電板２”の外周面に所定の面積で露出している。

【００５９】上記露出部に隣接している弾性板５”表面には、所定の面積の電極パッドＰ”がそれぞれ蒸着ないしスパッタ等で形成されている。この圧電板２”の外周面での各電極３１”，３２”の露出部と電極パッドＰ”とは、導電性樹脂（または導電性ペーストないし導電性接着剤）で互いに導通している。電極パッドＰ”には、図示しないボンディングワイヤないしリード線が接続される。

【００６０】なお、圧電板２”の圧電材料の分極方向については、前述の実施例１および実施例２と同様である。

（実施例３の作用効果）本実施例によれば、圧電板３’の全体が圧電材料の圧電定数d_{33}で作用するので、低電圧で駆動が可能でありながら、従来技術のユニモルフおよびバイモルフに比較して発生力は倍増し、最大変位も数割程度向上するという効果がある。

【００６１】（実施例３の製造方法）本実施例の圧電アクチュエータ１”は、前述の実施例１の製造方法の変形態様１や変形態様２などの製造方法を実施することで、製造することができる。各製造方法の特徴や利点の違いも、実施例１の製造方法の各変形態様と同様である。

（実施例３の変形態様）本実施例においても実施例２と同様に、弾性板５”をステンレス鋼などの導電性バネ弾性材料で形成し、各電極３１”，３２”が圧電板２”の両面から櫛の歯状に交互に形成されている変形態様が可能である。本変形態様では、圧電板２”の裏面は導電性接着剤で導電性の弾性板５”に接合されており、圧電板２”の表面全体には導電性の膜が形成されている。そして弾性板５”および導電性の膜は各電極３１”，３２”とそれぞれ導通しており、弾性板５”および導電性の膜のそれぞれにリード線ないしボンディングワイヤが接続されている。それゆえ、電極パッドＰ”は本変形態様には必要ない。ここで、導電性の膜は、導電性ペーストの印刷および焼成、蒸着、ＣＶＤおよびスパッタなどの方法で成膜することができる。

【００６２】本変形態様によれば、弾性板５”および導電性の膜がそれぞれ各電極３１”，３２”の全体と導通している共通電極の作用をする。それゆえ本変形態様によれば、駆動電源の回路と電極３１”，３２”と間の導通不良が起こりにくく、電極３１”，３２”が途中で断線しても問題がないので、実施例３よりも信頼性が向上するという効果がある。

【００６３】なお、本変形態様の圧電アクチュエータ１”は、実施例２の製造方法と同様の製造方法で製造が可能である。また、圧電板２’の表裏の各電極３１”，３２”の位置合わせは、ＬＳＩ等の集積回路の微細加工技術の応用で、容易かつ精密になすことが可能である。

【図面の簡単な説明】

【図１】　実施例１としての圧電アクチュエータの形状を示す斜視図

【図２】　実施例１としての圧電アクチュエータの構成を示す断面図

【図３】　実施例１の圧電板の分極方向と両電極とを示す断面図

【図４】　実施例１としての圧電アクチュエータの作用を示す組図

（ａ）印加電圧の無い状態での形状を示す断面図

（ｂ）印加電圧の有る状態での形状を示す断面図

【図５】　実施例１の圧電アクチュエータへのリード線の接続を示す斜視図

【図６】　レーザ加工による溝形成工程を示す模式図

【図７】　反応性イオンエッチング加工による溝形成工程を示す模式図

【図８】　実施例２としての圧電アクチュエータの形状を示す斜視図

【図９】　実施例２としての圧電アクチュエータの構成を示す断面図

【図１０】実施例２としての圧電アクチュエータの作用を示す組図

（ａ）印加電圧の無い状態での形状を示す断面図

（ｂ）部分的に印加電圧の有る状態での形状を示す断面図

（ｃ）全面的に印加電圧の有る状態での形状を示す断面図

【図１１】実施例３としての圧電アクチュエータの形状を示す斜視図

【図１２】従来技術としての圧電ユニモルフの形状を示

す斜視図

【図１３】従来技術としての圧電ユニモルフの作用を示す組図

（ａ）印加電圧の無い状態での形状を示す断面図

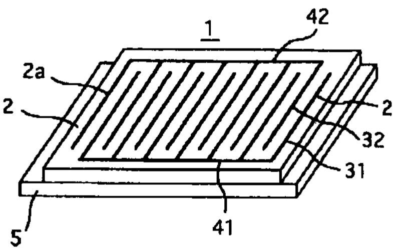
（ｂ）印加電圧の有る状態での形状を示す断面図

【符号の説明】

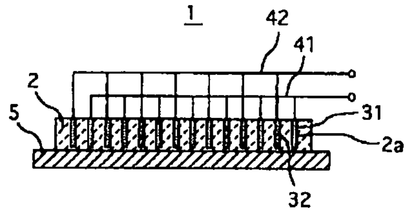
１，１’，１”：圧電アクチュエータ
２，２’，２”：圧電板　２ａ，２ａ’：溝
３１，３１’，３１”：第１電極　３２，３２’，３２”：第２電極
４１，４１’：第１共通電極　４２，４２’：第２共通電極
５，５’，５”：弾性板

６，６’：スイッチ　７，７’：駆動電源（比較的低電圧）　８：アース線
９：純水　１０：赤外レーザ　１１：レーザ集光光学系
１２：電極基板　１３：真空チャンバ　１４：磁場コイル
１５：高周波電源　１６：真空排気系　１７：プラズマ
d_{31}，d_{33}：圧電定数　Ｌ：リード線　Ｐ，Ｐ’：電極パッド
Ｐ１：圧電ユニモルフ（従来技術）
Ｐ２：圧電板　Ｐ３：電極　Ｐ５：円盤状弾性板
Ｐ６：スイッチ　Ｐ７：駆動電源（比較的高電圧）

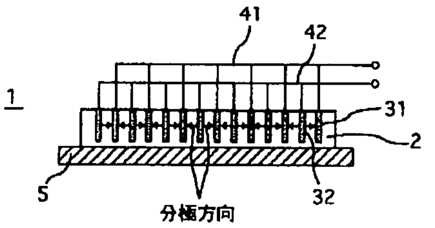
【図１】



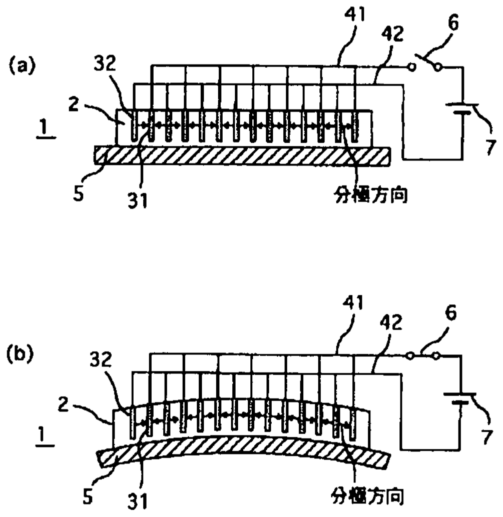
【図２】



【図３】



【図４】



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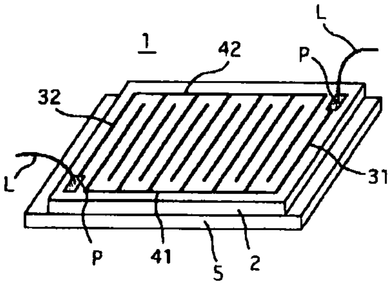

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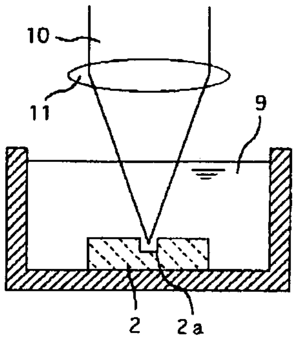
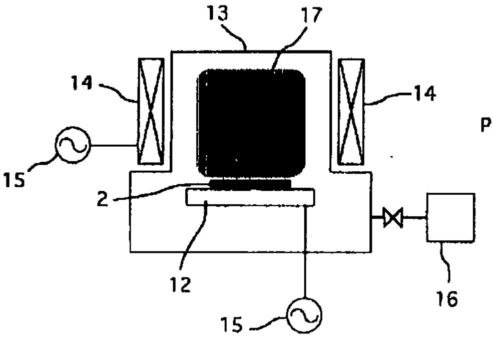
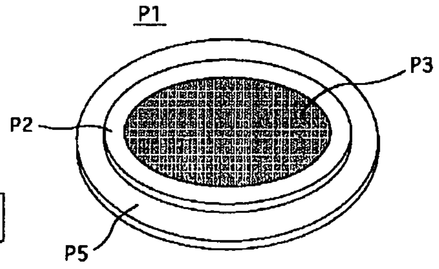


【図7】



【図１２】



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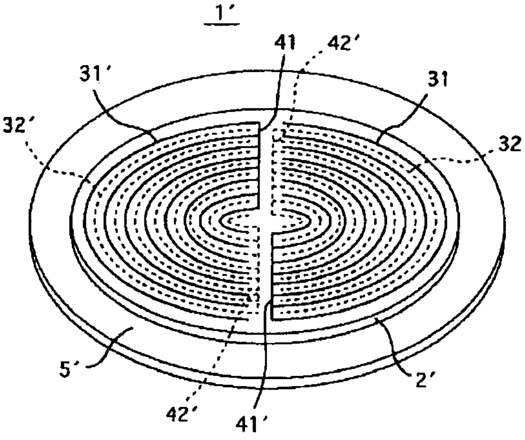
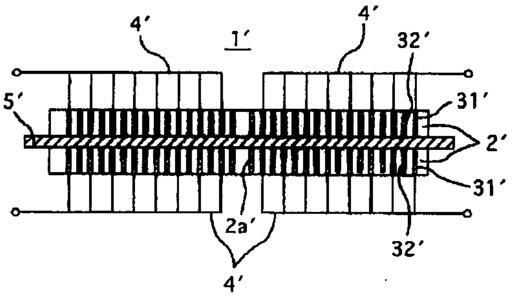
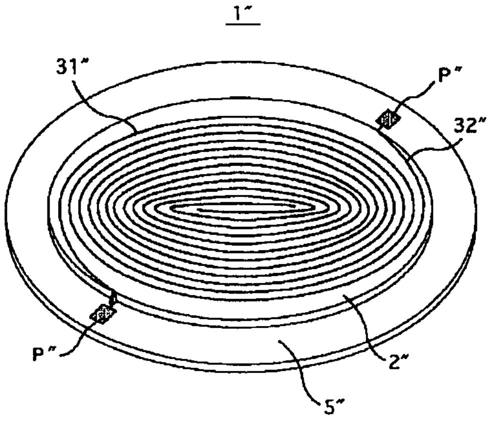


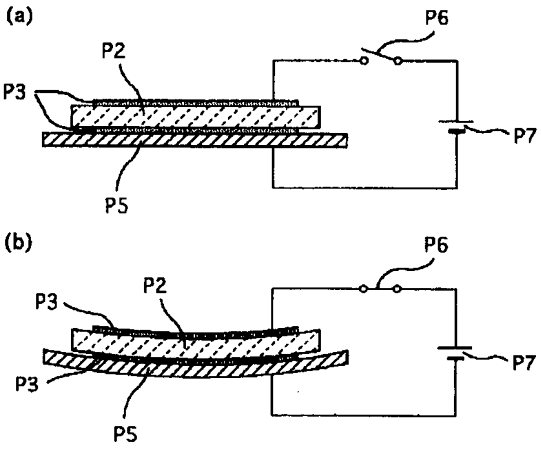
【図9】



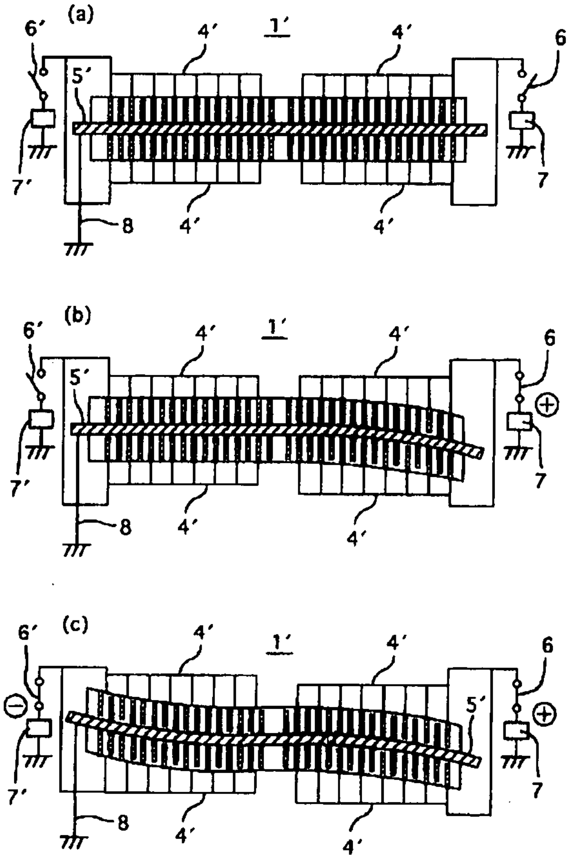
【図１１】



【図１３】



【図１０】



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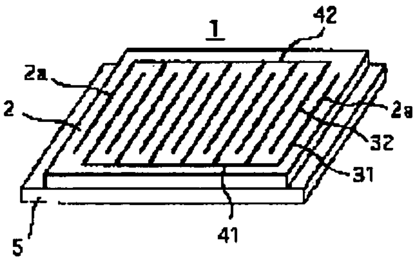
(71)Applicant : DENSO CORP

(72)Inventor : SAEKI KIYOSHI
IDOGAKI KOJI

(54) PIEZOELECTRIC ACTUATOR AND ITS MANUFACTURING METHOD

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a piezoelectric actuator that is a face deformation element for obtaining a sufficient generation force or a displacement, while operating at a low voltage and its manufacturing method.
SOLUTION: A piezoelectric actuator 1 has an elastic plate 5 that is a thin plate with spring elasticity, a piezoelectric plate 2 that is a thin plate made of a piezoelectric material being jointed onto the surface of the elastic plate 5, and a first electrode 31 and a second electrode 32 that are accommodated in a plurality of grooves 2a formed at the piezoelectric plate 2 with a gap that is equal to or less than the thickness of the piezoelectric plate 2 and are adjacent, while sandwiching a piezoelectric material. The piezoelectric actuator 1 can generate a sufficiently high electric field, even if an applied voltage is small, since the gap between both electrodes 31 and 32 is narrow and can utilize a piezoelectric constant d33 that is approximately two times larger than a piezoelectric constant d33, so that it can achieve a larger occurrence force and the maximum displacement even at a low voltage.



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CLAIMS

[Claim(s)]

[Claim 1] The elastic plate which is sheet metal with spring elasticity, and the piezo-electric plate which is sheet metal which consists of piezoelectric material joined to one [at least] front face of this elastic plate, The electrostrictive actuator which it fills up with electric conduction material into two or more slots currently formed in this piezo-electric plate at intervals of below the thickness of this piezo-electric plate, and is characterized by having the 1st electrode and the 2nd electrode which are formed from this electric conduction material that adjoins on both sides of this piezoelectric material mutually.

[Claim 2] Said slot in which said 1st electrode and said 2nd electrode are held is an electrostrictive actuator according to claim 1 which is carrying out opening to said elastic plate of said piezo-electric plate, and the front face facing in opposite directions.

[Claim 3] Said 1st electrode and said 2nd electrode are an electrostrictive actuator according to claim 1 currently arranged by turns in the shape of [of two combs which counter mutually in the field of the thickness direction of said piezo-electric plate] a gear tooth.

[Claim 4] Said 1st electrode and said 2nd electrode are an electrostrictive actuator according to claim 1 currently arranged by turns in the shape of [of two combs which counter mutually in a field parallel to the front face of said piezo-electric plate] a gear tooth.

[Claim 5] Said 1st electrode and said 2nd electrode are the shape of a straight line, the shape of a straight line which were refracted, and an electrostrictive actuator according to claim 1 currently arranged in one of configurations among circular, and the shape of a curve including the shape of a double helix and the configuration which these have compounded in a field parallel to the front face of said piezo-electric plate.

[Claim 6] Said piezo-electric plate is an electrostrictive actuator according to claim 1 which is divided into two or more partitions and has said two or more 1st electrodes which make a pair about this each partition, respectively, and said 2nd electrode.

[Claim 7] The slot formation process which forms two or more slots at spacing shorter than the thickness of this piezo-electric plate in this piezo-electric plate from the front face of the piezo-electric plate which is sheet metal which consists of piezoelectric material joined or joined to the front face of the elastic plate which is sheet metal with spring elasticity, The electrode formation process which forms the 1st electrode and the 2nd electrode which are filled up with electric conduction material into this slot, and adjoin on both sides of this piezoelectric material mutually, The manufacture approach of an electrostrictive actuator which impresses the high voltage between this 1st electrode and this 2nd electrode, and is characterized by having the polarization process to which polarization of this piezoelectric material inserted between these two electrodes is carried out.

[Claim 8] Said slot formation process is the manufacture approach of an electrostrictive actuator according to claim 7 which is the process which forms said slot by either among dicing processing, laser beam machining, and reactive-ion-etching processing.

[Claim 9] Said electrode formation process is the manufacture approach of an electrostrictive actuator according to claim 7 which is the process which forms said 1st electrode and said 2nd electrode by either among CVD, sputtering, the imprinting of a conductive paste, electroless deposition, and vacuum evaporationo.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention belongs to the technical field of the electrostrictive actuator which is a field deformation component similar to a piezo-electric uni-morph or piezo-electric bimorph.
[0002]
[Description of the Prior Art] As an electrostrictive actuator which is the field deformation component of the conventional technique, there are a piezo-electric uni-morph and piezo-electric bimorph. These usually consist of a piezo-electric plate which are the elastic plate which is sheet metal with spring elasticity, and sheet metal which consists of piezoelectric material joined to one [at least] front face of this elastic plate, and an electrode of a pair formed thru/or joined by both sides of each piezo-electric plate, respectively.
[0003] If an electrical potential difference is impressed to the electrode of a top Norikazu pair, the electric field of the field strength which broke applied voltage by thickness will arise in the thickness direction of a piezo-electric plate, and a piezo-electric plate will produce at least a field domestic disturbance perpendicular to the thickness direction in proportion to the product of field strength and a piezoelectric constant d31 (or pressure which is going to start at least a field domestic disturbance). or [consequently, / that field deformation components such as a uni-morph and bimorph, curve in one side] -- or the force used as an anti-wax is generated.
[0004] If the piezo-electric uni-morph P1 is taken up as an example, as shown in drawing 12 , the piezo-electric plate P2 is joined to one side of the metal disc-like elastic plate P5, and as shown in drawing 13 (a), the electrode P3 is formed in both sides of the piezo-electric plate P2, respectively. If an electrical potential difference is impressed to the above-mentioned two electrodes P3, as shown in drawing 13 (b), the piezo-electric plate P2 will contract to the field inboard which intersects perpendicularly with the direction of polarization, and the uni-morph P1 whole will curve and deform. Under the present circumstances, the deformation pressure (stress at the time of immobilization) of the piezo-electric plate P2 is proportional to the field strength and the piezoelectric constant d31 which broke applied voltage by thickness of the piezo-electric plate P2.
[0005]
[Problem(s) to be Solved by the Invention] In an above-mentioned uni-morph and bimorph, in order to make it operate by the low battery, the thickness of a piezo-electric plate is formed thinly and there is a means by which field strength strong enough is obtained also by the low battery. However, since the cross section of field inboard will become small if thickness of a piezo-electric plate is made thin, the force generated in field inboard cannot become weak, and sufficient generating force cannot be acquired. So, the sufficient generating force and a sufficient variation rate cannot be obtained, operating by the low battery depending on the above-mentioned conventional technique.
[0006] Then, this invention makes it the technical problem which should be solved to offer the electrostrictive actuator which is the field deformation component which can obtain at least one side among sufficient generating force and a variation rate, and its manufacture approach, operating by the low battery.
[0007]
[The means for solving a technical problem, and its operation and effectiveness] In order to solve the above-mentioned technical problem, artificers invented the following means.
[Electrostrictive actuator]
(The 1st means) The 1st means of this invention is an electrostrictive actuator according to claim 1. The high voltage is applied to the piezo-electric plate between the 1st electrode and the 2nd electrode in the manufacture process, and polarization of piezoelectric material is beforehand formed in the sense which intersects perpendicularly with each electrode surface of field inboard.

[0008] Here, semiconductor materials, such as insulating ingredients, such as conductive ingredients, such as metals, such as stainless steel, copper, and a copper alloy, or synthetic resin, and glass, or silicon, are sufficient as the ingredient which forms the elastic plate. Moreover, the ingredient which forms the piezo-electric plate can be suitably chosen from the piezoelectric material which produces the piezo-electric effect or an inverse piezoelectric effect by impression of an electrical potential difference, for example, PZT (PZT) of electrostrictive ceramics can be used for it. On the other hand, the ingredient which forms each electrode can be suitably chosen from conductive ingredients, for example, metals, such as aluminum, gold, silver, platinum, a tungsten, copper, and these alloys, can be used for it.

[0009] With this means, in two or more slots currently formed at intervals of below the thickness of a piezo-electric plate, it fills up with electric conduction material, adjoins on both sides of this piezoelectric material mutually, and the 1st electrode and the 2nd electrode are formed. so -- if an electrical potential difference is impressed between the above-mentioned two electrodes -- field inboard -- electric field -- generating -- the product of field strength and a piezoelectric constant d33 -- it is proportional -- field inboard (direction parallel to electric field) with a piezo-electric plate perpendicular to the thickness direction -- telescopic motion -- a variation rate or the flexible force is produced. Here, since a heavy current community occurs also by the low battery and field strength is not influenced by the thickness of a piezo-electric plate so that spacing of a slot, i.e., spacing of two electrodes, is narrow, only the thickness which can demonstrate sufficient deformation force can be given to a piezo-electric plate.

[0010] Under the present circumstances, if spacing of the two electrodes which adjoin mutually is fully small to the thickness of a piezo-electric plate, even if the electrical potential difference to impress is a low battery, field strength high enough will arise in field inboard, and sufficient bending deformation for an electrostrictive actuator or the bending force of this means will be generated. Moreover, unlike the conventional technique in which the piezoelectric constant d31 was used, flexible deformation of field inboard or the flexible force occurs by the piezoelectric constant d33. Here, since a piezoelectric constant d33 is usually large about 2 times compared with a piezoelectric constant d31, if field strength is the same, the deformation force which the electrostrictive actuator of this means generates will become large about 2 times compared with the conventional technique. This effectiveness is demonstrated also when spacing of two electrodes is comparable as the thickness of a piezo-electric plate, and even if it is the same field strength, the flexible force of being twice [about] many as this is acquired.

[0011] Moreover, since the width of face of a slot, i.e., the width of face of two electrodes, is usually smaller than spacing of two electrodes, the magnitude of the variation rate of this means also becomes larger than that of the conventional technique. And in order to obtain a variation rate (it is proportional to the product of field strength and a piezoelectric constant d33) equivalent to the conventional technique by the electrostrictive actuator of this means, this means of the electrical potential difference to impress is lower than the conventional technique, and it ends. Therefore, according to this means, an electrostrictive actuator can be operated with applied voltage much lower than the conventional technique, and it is effective in the deformation force and deformation becoming larger than the conventional technique.

[0012] (The 2nd means) The 2nd means of this invention is an electrostrictive actuator according to claim 2. It is able to form a slot in a precision with this means, from the front face of the piezo-electric plate joined to the elastic plate, making full use of ultra-fine processing technology, since each slot in which two electrodes are held is carrying out opening to the front face of a piezo-electric plate. Moreover, since a slot is formed by processing from the same front face, it becomes easy to be able to do easily, and for the precise alignment of the slot of the 1st electrode and the slot of the 2nd electrode to keep spacing of both slots constant to a precision, and to process it into it. Furthermore, it is possible to form two electrodes at once from one field of a piezo-electric plate, and the process which forms two electrodes in both sides of a piezo-electric plate as compared with the case where the slot of each electrode is carrying out opening, respectively is also simplified. In addition, since a slot can be formed after joining a piezo-electric plate to an elastic plate, it is hard coming to generate a crack to the piezo-electric plate with which the slot is formed, and the handling under manufacture also becomes easy.

[0013] Therefore, according to this means, in addition to the effectiveness of the 1st above-mentioned means, it is effective in manufacture of the electrostrictive actuator of this invention becoming easy. In addition, although the depth of flute is stopped in the range at which an insulation is maintained between two electrodes and an elastic plate when an elastic plate consists of conductive ingredients, such as a metal, the elastic plate could become and come out of insulating ingredients, such as synthetic resin and glass, and, in a certain case, the slot may penetrate the elastic plate. In the case of the latter, after a piezo-electric plate is joined to an elastic plate, a slot will be formed, but since electric field can be applied to a piezo-electric plate more widely (deeply) than the case of the former, the generating force and deformation increase rather than

the former.
[0014] (The 3rd means) The 3rd means of this invention is an electrostrictive actuator according to claim 3. With this means, one side is formed in the plane of composition of the piezo-electric plate which counters an elastic plate among two electrodes into the slot which is carrying out opening, and another side is formed in the slot which is carrying out opening to the front face of the piezo-electric plate which faces in opposite directions to an elastic plate. That is, two electrodes are formed by turns from the front flesh side of a piezo-electric plate. So, since one field can be made into a connection side with one electrode and the field of another side can be made into the connection side to the electrode of another side, connection between two electrodes and a drive power source becomes easy, and a possibility of connecting too hastily in respect of the same disappears.
[0015] Therefore, according to this means, in addition to the effectiveness of the 1st above-mentioned means, it is effective in connection between two electrodes and a drive power source not only becoming easy, but the short circuit between two electrodes being prevented.
(The 4th means) The 4th means of this invention is an electrostrictive actuator according to claim 4.
[0016] With this means, since the pattern on the piezo-electric plate of two electrodes is formed only in a straight line, respectively and can arrange two electrodes most densely to the area of the front face of a piezo-electric plate, even if applied voltage is low, the big generating force can be acquired. Moreover, an electrostrictive actuator does not curve in the shape of the abbreviation spherical surface like the conventional technique, and forms curvature and a primary curved surface in an one direction.
[0017] Therefore, according to this means, in acquiring a variation rate big enough thru/or the generating force with lower applied voltage in addition to the effectiveness of the 1st above-mentioned means, it is effective in an electrostrictive actuator deforming into a primary curved surface.
(The 5th means) The 5th means of this invention is an electrostrictive actuator according to claim 5.
[0018] since two electrodes are formed in a piezo-electric plate by the pattern of the arbitration containing a straight line or a curve in this means -- an electrostrictive actuator -- a primary curved surface -- positive/negative -- it can be made to deform into any quadratic surface Therefore, according to this means, in addition to the effectiveness of the 1st above-mentioned means, it is effective in the ability to design to arbitration the deformation configuration and the direction which is going to deform of an electrostrictive actuator.
[0019] (The 6th means) The 6th means of this invention is an electrostrictive actuator according to claim 6. Since mutually-independent [of the applied voltage] can be carried out and it can be controlled by this means for every partition, it is possible to give the direction and deformation of deformation to every partition according to an individual, and it becomes possible to make an electrostrictive actuator transform into a complicated configuration.
[0020] Therefore, according to this means, in addition to the effectiveness of the 1st above-mentioned means, deformation can be controlled according to an individual for every partition, and it is effective in it becoming possible to make an electrostrictive actuator transform into a complicated configuration.
[The manufacture approach of an electrostrictive actuator]
(The 7th means) The 7th means of this invention is an electrostrictive actuator according to claim 7.
[0021] The electrostrictive actuator of the 1st means is manufactured according to the polarization process which the high voltage is impressed [process] and carries out polarization of the piezoelectric material to the slot formation process which forms in this piezo-electric plate two or more slots at spacing shorter than the thickness of the front face of the piezo-electric plate which is sheet metal which consists of piezoelectric material at least to this piezo-electric plate, and the electrode formation process which is filled up with electric conduction material into this slot, and forms the 1st electrode and the 2nd electrode between two electrodes with this means. The processing technique which diversion of the ultra-fine processing technology of a semi-conductor could be possible to the slot formation process, and could form the slot in it easily, and has matured in each engineering field also in the electrode formation process can be diverted to some other purpose. Moreover, a polarization process is also fundamentally [as the process currently performed by the usual piezoelectric device] the same, and there is no technical difficulty in the manufacture approach of this means.
[0022] Therefore, according to this means, it is effective in the ability to manufacture the electrostrictive actuator of the 1st above-mentioned means easily by diversion of the processing technique which has already matured.
(The 8th means) The 8th means of this invention is the manufacture approach of an electrostrictive actuator according to claim 8. With this means, one of processing techniques is used for a slot formation process among dicing processing, laser beam machining, and reactive-ion-etching processing. It ends with a cheap

and simple processing facility in dicing processing, and there is an advantage that processing is performed promptly in it. On the other hand, there is an advantage that the pattern of the slot on the front face of a piezo-electric plate can be designed to arbitration also including a curve in laser beam machining and reactive-ion-etching processing.

[0023] (The 9th means) The 9th means of this invention is the manufacture approach of an electrostrictive actuator according to claim 9. With this means, one of processing techniques is used for an electrode formation process among CVD (chemical vapor deposition), sputtering, the imprinting of a conductive paste, electroless deposition, and vacuum evaporationo. In forming two electrodes comparatively precisely, there is an advantage that electrode formation of two or more sheets is attained at once in CVD, vacuum evaporationo, and sputtering. On the other hand, in ending with a cheap and simple processing facility, there is an advantage that floor to floor time is comparatively short, and ends in the imprinting and electroless deposition of a conductive paste.

[0024] In addition, if it removes after termination of an electrode formation process after using this mask material also with an electrode formation process when mask material is joined to the front face of a piezo-electric plate with the slot formation process, since excessive electric conduction material is removed with this mask material, it is rational. Conversely, when mask material is not joined to the front face of a piezo-electric plate with a slot formation process, the excessive electric conduction material deposited on the front face of a piezo-electric plate may be removed by machining of grinding etc.

[0025]

[Embodiment of the Invention] an understanding which can be carried out to this contractor about the electrostrictive actuator of this invention, and the gestalt of operation of the manufacture approach -- profit **** -- clear [like] in the following examples -- and it fully explains.

[Example 1]

(Configuration of an example 1) As shown in drawing 1 , as for the electrostrictive actuator 1 of this example, the plan type is carrying out the rectangular configuration. That is, the electrostrictive actuator 1 consists of a rectangular elastic plate 5, a rectangular piezo-electric plate 2 joined to the front face of one of these with epoxy system adhesives, and each electrodes 31, 32, 41, and 42 held in slot 2a currently formed in the piezo-electric plate 2.

[0026] An elastic plate 5 is sheet metal with spring elasticity, and is a plate of stainless steel with width of face of 10mm, a depth [of 15mm], and a thickness of 0.05mm. The piezo-electric plate 2 is sheet metal which consists of PZT piezoelectric material, and is a plate with width of face of 8mm, a depth [of 12mm], and a thickness of 0.05mm. It is formed by turns in the shape of [of two combs with which slot 2a counters the piezo-electric plate 2 mutually in a field parallel to a front face] a gear tooth. It fills up with electric conduction material into slot 2a of the shape of a gear tooth of one comb, and the 1st electrode 31 is formed, it fills up with the same electric conduction material into slot 2a of the shape of a gear tooth of the comb of another side, and the 2nd electrode 32 is formed. The 1st electrode 31 and the 2nd electrode 32 of each other are insulated on both sides of the piezoelectric material of the piezo-electric plate 2. It has connected with the 1st community electrode 41 currently similarly formed in slot 2a by electric conduction material by the end, and all the 1st electrode 31 has connected all the 2nd electrode 32 with the 2nd community electrode 42 currently similarly formed in slot 2a by electric conduction material by the end similarly. Although the above-mentioned electric conduction material is aluminum, changing into gold, a tungsten, etc. suitably is also possible.

[0027] As shown in drawing 2 , opening of all the slot 2a is carried out to the front face of the piezo-electric plate 2 which faces in opposite directions to the elastic plate 5, electric conduction material is introduced in slot 2a from this opening, and each electrodes 31, 32, 41, and 42 are formed. In addition, it connects with a bonding wire or lead wire, respectively, and the 1st community electrode 41 and the 2nd community electrode 42 can receive now the applied voltage from a drive power source (figure abbreviation).

[0028] It is formed by depth of 0.045mm (90% of the thickness of the piezo-electric plate 2), and width of face of 0.015mm, and each above-mentioned electrodes 31, 32, 41, and 42 of spacing of the 1st electrode 31 and the 2nd electrode 32 are fixed, and are 0.03mm (3/5 of the thickness of the piezo-electric plate 2). That is, as shown in drawing 3 , the piezoelectric material polarized in the perpendicular direction is pinched with the front face of two electrodes between the 1st electrode 31 and the 2nd electrode 32 by the thickness equivalent to this inter-electrode spacing.

[0029] (The operation effectiveness of an example 1) In the condition that the electrical potential difference is not impressed, the electrostrictive actuator 1 of this example is carrying out plate-like as a whole, as shown in drawing 4 (a). On the other hand, as shown in drawing 4 (b), in the condition that a switch 6 closes and the electrical potential difference is impressed from the cell 7 as a drive power source, two electrodes 31 and 32 elongate piezoelectric material in the direction (direction parallel to electric field) by which the laminating is carried out by turns. Under the present circumstances, elongation percentage is proportional in the range predetermined in applied voltage at the product of the piezoelectric constant d33 (constant) of the piezo-electric plate 2, and the field strength by the applied voltage of a cell 7. Since this field strength is the value which broke applied voltage at intervals of each electrodes 31 and 32, even if it is low applied voltage, in the electrostrictive actuator 1 of this example as mentioned above with the above-mentioned spacing much narrower than the thickness of the piezo-electric plate 2, field strength big enough produces it. Moreover, only the thickness which produces bending moment also with the sufficient thickness of the piezo-electric plate 2 to bend an elastic plate 5 is secured.

[0030] Consequently, the piezo-electric plate 2 produces the elongation force big enough, elongates only the specified quantity in the direction of a laminating of each electrodes 31 and 32, and bends an elastic plate 5 with predetermined curvature (it bends also joining the piezo-electric plate 2 to an elastic plate 5). By this bending deformation, the electrostrictive actuator 1 of this example forms a primary curved surface as a whole. According to the electrostrictive actuator 1 of this example, as explained in full detail above, even if applied voltage is comparatively low, sufficient bending deformation force is produced and it is effective in the ability to, generate bending deformation big enough as a result.

[0031] (Application of an example 1) Since the applied voltage needed for a drive is a low battery comparatively when the electrostrictive actuator 1 of this example is adopted as a micro machine, an electrostrictive actuator 1 can be driven by the cell which did not require a high-voltage transformer assembly but was carried in the micro machine. Therefore, it is effective in it becoming easy to constitute a micro machine without an electric supply cable as a simple substance. Moreover, since the high voltage is not needed, there is effectiveness that prevention of a short circuit is also easy and-izing of the part and the micro machine can be carried out [small lightweight].

[0032] (Deformation mode of an example 1) In the electrostrictive actuator 1 of the above-mentioned example 1, the deformation mode which forms an elastic plate 5 with insulating glass thru/or synthetic resin, penetrates the piezo-electric plate 2, forms slot 2a, and forms two electrodes 31 and 32 over the whole thickness of the piezo-electric plate 2 can also be carried out. According to this strange gestalt of the, it is effective in the bigger generating force and deformation being obtained.

[0033] In addition, since the common electrodes 41 and 42 are only functioning as a track, it does not need to be formed over the whole thickness of the piezo-electric plate 2. Furthermore, although it is the same also in the example 1, it is desirable [the common electrodes 41 and 42] to be formed by width of face larger than electrodes 31 and 32, when securing a flow with electrodes 31 and 32 and the electrode pad P.

[0034] Moreover, a deformation mode like the bimorph to which it is the same configuration as an example 1 or its deformation mode, and the piezo-electric plate 2 is joined by front flesh-side both sides of an elastic plate 5, respectively can also be carried out.

(The manufacture approach of an example 1) The manufacture approach of the electrostrictive actuator 1 of this example is constituted in order of the junction process, the slot formation process, the electrode formation process, and the polarization process.

[0035] A junction process is a process which prepares the elastic plate 5 and the piezo-electric plate 2 which are fabricated by the sheet metal of a predetermined dimension, doubles mutual bearing, and carries out junction immobilization of the piezo-electric plate 2 with adhesives on one front face of an elastic plate 5. At this process, before moving to the following slot formation process, adhesives are fully stiffened and junction to the piezo-electric plate 2 and an elastic plate 5 is made perfect. Here, before an elastic plate 5 and the piezo-electric plate 2 are cut out by the predetermined dimension which constitutes an electrostrictive actuator 1, both 5 and 2 of each other are joined, and after all processes are completed, the manufacture approach judged in the above-mentioned predetermined dimension can also be taken. According to this approach, it is possible like many semiconductor chips to manufacture many electrostrictive actuators 1 at once.

[0036] A slot formation process is a process which forms two or more slot 2a at spacing shorter than the thickness of the piezo-electric plate 2 in the piezo-electric plate 2 by the above-mentioned pattern (refer to drawing 1) from the front face of the piezo-electric plate 2 joined to the front face of an elastic plate 5. In this example, since all the patterns of slot 2a consist of linear segments, dicing processing is used for a slot formation process, it is cut mechanically, and slot 2a of the predetermined depth is formed.

[0037] An electrode formation process is a process which forms the 1st electrode 31 and the 2nd electrode 32 which are filled up with electric conduction material into slot 2a, and adjoin mutually on both sides of the piezoelectric material of the piezo-electric plate 2. In this example, the processing approach which inserts with a roller the conductive paste which contains silver impalpable powder so much in the solvent of a minute amount in all slot 2a is taken. Going and coming back to a roller from the direction of slanting to slot 2a, it fills up all slot 2a with the above-mentioned paste completely in the case of imprinting. If the above-mentioned imprinting is performed in the decompressed ambient atmosphere here, since air bubbles (void) cannot remain in the inner part of slot 2a easily, it is more desirable. In addition, the excessive conductive paste adhering to the front face of the piezo-electric plate 2 will be finely removed, if it wipes off with a solvent after stenciling with a roller, and the worries about a short circuit disappear.

[0038] After a solvent evaporates from the above-mentioned paste with which slot 2a was filled up, the piezo-electric plate 2 is put into a heat treating furnace with an elastic plate 5, a temperature up is carried out even to proper temperature, silver impalpable powder is dissolved, and the silver electrodes 31, 32, 41, and 42 are calcinated. That is, it is cooled after heat treatment, and solidifies continuously in silver fang furrow 2a, and each electrodes 31, 32, 41, and 42 are formed. After each electrodes 31, 32, 41, and 42 are formed with an electrode formation process, other one lead wire is joined to either among 1, the 2nd electrode 32, and the 2nd community electrode 42 among the 1st electrode 31 and the 1st community electrode 41 at either. In the case of this example, as shown in drawing 5 , the conductive paste which uses silver as a principal component is printed and calcinated, and each electrode pad P is formed in the edge of the 1st electrode 31 and the edge of the 2nd electrode 32 nearest to the side edge of the piezo-electric plate 2. And lead-wire L is connected to each electrode pad P with soldering, respectively (adhesion by electroconductive glue is sufficient).

[0039] Finally, at a polarization process, the high voltage is impressed between the 1st electrode 31 and the 2nd electrode 32 through each lead-wire L, and polarization of the piezoelectric material of two electrodes 31 and the piezo-electric plate 2 inserted among 32 is carried out. The electrostrictive actuator of this example is manufactured by the manufacture approach of the above this example. According to the manufacture approach of this example, the facility which manufacture takes is cheap and simple, and it is especially effective in the ability to manufacture the quick electrostrictive actuator of the above-mentioned cheaply by low production of a prototype etc.

[0040] (Deformation mode 1 of the manufacture approach of an example 1) The manufacture approach which uses a laser process for a slot formation process after the same junction process as an example 1 as a deformation mode of the manufacture approach of this example, and uses CVD for an electrode formation process is possible. In the slot formation process by the laser process, as shown in drawing 6 , wavelength condenses the infrared laser light 10 which is about 1 micrometer with a condenser lens 11, and irradiates the part which should form slot 2a of the piezo-electric plate 2 dipped in pure water 9. Then, by the local temperature rise by the concentration irradiation of infrared laser light, PZT which forms the piezo-electric plate 2 reacts chemically with pure water 9, and corrodes by the irradiated part, and slot 2a is formed gradually. By making a laser beam 10 scan along with the pattern which should form slot 2a on the piezo-electric plate 2, all slot 2a that should hold each electrodes 31, 32, 41, and 42 is formed.

[0041] In the electrode formation process by CVD, the mask is formed in the front face of piezo-electric plates 2 other than slot 2a by the resist, and patterning is carried out so that conductive material (this example silver) may adhere in slot 2a. Consequently, in slot 2a, each electrodes 31, 32, 41, and 42 are formed, and the front face of the other piezo-electric plates 2 is maintained at clarification. In addition, the conductive material deposited on the front face of the piezo-electric plate 2 may be removed by machining and the chemical treatment of cutting, polishing, etc. without carrying out patterning by mask material.

[0042] The electrode pad P which should connect the bonding wire replaced with lead-wire L is formed in slot 2a and coincidence with the above-mentioned electrode formation process. Since the advantage of the manufacture approach of this deformation mode is not based on machining but forms slot 2a by laser beam machining, it is being able to form slot 2a of thinner width of face at narrower spacing, and, so, is effective in actuation becoming possible by the low battery more. Incidentally, the slot 2a piece minimum is about 2 micrometers in about 5 micrometers and ultraviolet laser at infrared laser, and the minimum of spacing of slot 2a is about 10 micrometers in about 30 micrometers and ultraviolet laser at infrared laser.

[0043] (Deformation mode 2 of the manufacture approach of an example 1) The manufacture approach which uses reactive ion etching for a slot formation process after the same junction process as an example 1 as a deformation mode of the manufacture approach of this example, and uses sputtering for an electrode formation process is possible. In the slot formation process by reactive ion etching, as shown in drawing 7 , the piezo-electric plate 2 with which patterning of the front face is carried out is put in and processed by the mask material of a resist in the vacuum chamber 13 for processing of a reactive ion etching system. In this equipment, the corrosion by the chemical reaction takes place by the part which the plasma 17 of reactant gas occurs and should form slot 2a of the piezo-electric plate 2 in an alternating current magnetic field with the magnetic field coil 14 driven by AC power supply 15 of a RF. under the present circumstances -- as reactant gas -- CF4 and Cl2 etc. -- it can be used. On the other hand, plurality is arranged in on the electrode substrate 12, and the high voltage is impressed to the piezo-electric plate 2 joined to the elastic plate 5 from AC power supply 15 of a RF through the electrode substrate 12. In addition, the vacuum chamber for processing is maintained at the proper degree of vacuum by the evacuation system 16.

[0044] It leaves the mask used with the above-mentioned slot formation process to the front face of piezo-electric plates 2 other than slot 2a, and conductive material is made to adhere in slot 2a by sputtering in the electrode formation process by sputtering. Consequently, in slot 2a, each electrodes 31, 32, 41, and 42 are formed, and the front face of the other piezo-electric plates 2 is maintained at clarification if a mask is removed. The electrode pad P which should connect the bonding wire replaced with lead-wire L is formed in slot 2a and coincidence with the above-mentioned electrode formation process.

[0045] Since the advantage of this strange gestalt's [the] manufacture approach forms slot 2a and each electrodes 31, 32, 41, and 42 using reactive ion etching and sputtering, it is that can process many piezo-electric plates 2 at once, and mass production method becomes easy.

(Formation of the electrode pad of an example 1) The electrode pad P can be formed by membrane formation of CVD, sputtering, vacuum evaporationo or the aluminum by electroless deposition, silver, gold, or nickel. So, as mentioned above, in case electrodes 31, 32, 41, and 42 are formed by these processing methods, forming in coincidence is rational. To the electrode pad P of membrane formation, connection with a voltage source is possible by wirebonding.

[0046] (Deformation mode of an example 1) Although the piezo-electric plate 2 was joined only to one side of an elastic plate 5 like the uni-morph in the electrostrictive actuator 1 of the above-mentioned example 1, the deformation mode to which the piezo-electric plate 2 is joined by both sides of an elastic plate 5 like bimorph, respectively is also possible. According to this strange gestalt's of the electrostrictive actuator, it is effective in the ability to double the generating force compared with the above-mentioned electrostrictive actuator 1.

[0047] [Example 2]

(Configuration of an example 2) this invention -- an example -- two -- ****** -- an electrostrictive actuator -- one -- ' -- drawing 8 -- and -- drawing 9 -- being shown -- as -- one -- a sheet -- being disc-like -- stainless steel -- make -- sheet metal -- from -- becoming -- being disc-like -- an elastic plate -- five -- ' -- an elastic plate -- five -- front -- a flesh side -- both sides -- electroconductive glue -- respectively -- joining -- having -- **** -- two -- a sheet -- piezo-electricity -- a plate -- two -- ' -- from -- becoming . The piezo-electric plate 2 is sheet metal which consists of PZT like an example 1, and is carrying out discoid with a little small diameter from the elastic plate 5.

[0048] Two piezo-electric plates 2' is divided into two partitions as shown in drawing 8 , and these two partitions correspond on the front reverse side about two piezo-electric plates 2'. piezo-electricity -- a plate -- two -- ' -- each -- a partition -- ******** -- respectively -- a pair -- making -- plurality -- the -- one -- an electrode -- 31 -- ' -- and -- the -- two -- an electrode -- 32 -- ' -- having -- **** . moreover, each piezo-electric plate 2 -- each partition -- respectively -- every -- the [which has connected 1st electrode 31'] -- 1 common electrode 41' -- respectively -- every -- the [which has connected 2nd electrode 32'] -- it has 2 common electrodes 42.

[0049] Two or more 1st electrode 31' draws the pattern of an abbreviation semicircle arc on the front face of piezo-electric plate 2', is formed, respectively, and two 1st community electrode 41' also draws a pattern on the front face of piezo-electric plate 2' in the shape of a straight line, respectively, and they is formed. On the other hand, two or more 2nd electrode 32' also draws the pattern of an abbreviation semicircle arc on the rear face (field joined to elastic plate 5') of piezo-electric plate 2', and is formed, respectively, and two 2nd community electrode 42' also draws a pattern on the rear face of piezo-electric plate 2' in the shape of a straight line, respectively, and is formed in it.

[0050] That is, 1st electrode 31' and 2nd electrode 32' are arranged by turns in the shape of [of two combs which counter mutually in the field of the thickness direction of each piezo-electric plate 2'] a gear tooth, as shown in drawing 9 . 1st electrode 31' and 1st community electrode 41' are connected to lead wire by the electrode pad (figure abbreviation) formed for every partition, respectively. On the other hand, it connects with the elastic plate 5 through electroconductive glue, and 2nd electrode 32' and the 2nd community electrode 42 are further connected to other lead wire (figure abbreviation) through the elastic plate 5. So, it is also possible for there to be no need for 2nd community electrode 42', and to omit and constitute 2nd community electrode 42'.

[0051] The piezoelectric material inserted into 1st electrode 31' and 2nd electrode 32' is polarized by the field inboard of piezo-electric plate 2' at piezo-electric plate 2' by the side of drawing Nakagami in the direction of 2nd electrode 32' to 1st electrode 31'. On the other hand, the piezoelectric material which forms

piezo-electric plate 2' by the side of drawing Nakashita is conversely polarized in the direction of 1st electrode 31' to 2nd electrode 32'.
(The operation effectiveness of an example 2) electrostrictive actuator 1' of this example -- two piezo-electric plates 2 -- since 'two-electrodes 31' currently formed inside, 32' are divided into the partition of two right and left as shown in drawing 10 (a), it is possible to control each partition separately. Under the present circumstances, piezo-electric plate 2', 2nd electrode 32', and 2nd community electrode 42' are grounded through an earth wire 8. On the other hand, it connects with circuit 4' and may flow through 1st electrode 31of piezo-electric plate 2' of front flesh side of partition of this drawing Nakamigi hemihedry' to the forward drive power source 7 through a switch 6 further. On the other hand, it connects with other circuit 4', and may flow through 1st electrode 31of piezo-electric plate 2' of front flesh side of partition of left half plane in said drawing' in negative drive power-source 7' through switch 6' further.
[0052] That is, if a switch 6 is closed and a forward electrical potential difference is impressed only to circuit 4' of the partition by the side of this drawing Nakamigi as shown in drawing 10 (b), only a right half plane will turn at electrostrictive actuator 1' convex, and will deform it. Furthermore, if switch 6' is closed and a negative electrical potential difference is impressed only to circuit 4' of the partition of the left-hand side in the said drawing as shown in drawing 10 (c), it will turn at the left half plane of electrostrictive actuator 1' convex, and it will deform.
[0053] the above -- having explained in full detail -- as -- this example -- an electrostrictive actuator -- one -- ' -- **** -- a pair -- becoming -- an electrode -- 31 -- ' -- 32 -- ' -- two -- a ** -- a partition -- being divided -- **** -- since -- two -- a ** -- a partition -- respectively -- separate -- being controllable -- ** -- saying -- effectiveness -- it is . Moreover, since piezo-electric plate 2' is joined by both sides of elastic plate 5', compared with the electrostrictive actuator 1 of a configuration of that the piezo-electric plate 2 does not spread on one side of an elastic plate 5 like an example 1, there is effectiveness of the ability to make the generating force double like the bimorph to a uni-morph.
[0054] (The manufacture approach of an example 2) Electrostrictive actuator 1' of this example can be manufactured by enforcing the manufacture approaches, such as the deformation mode 1 of the manufacture approach of the above-mentioned example 1, and the deformation mode 2, to the front flesh side of piezo-electric plate 2'. The description of each manufacture approach and the difference in an advantage are the same as that of each deformation mode of an example 1.
[0055] In addition, the alignment of each electrode 31' of the front flesh side of piezo-electric plate 2' and 32' is application of the ultra-fine processing technology of integrated circuits, such as LSI, and can be made [easy and] to a precision.
(Deformation mode 1 of an example 2) It is possible to divide into each front face of each piezo-electric plate 2' for every partition, to print and calcinate a conductive paste, to form the conductive metal (for example, silver) film, to cover each whole partition, and to replace with the electrode pad of an example 2. That is, in this deformation mode, it is possible to use elastic plate 5' and conductive membrane formation of each partition as a common electrode, respectively.
[0056] So, in this deformation mode, 1st community electrode 41' and 2nd community electrode 42' are unnecessary, and can simplify a slot formation process. Therefore, according to this strange gestalt of the, since conductive membrane formation of each partition also acts as a common electrode, it is effective in the possibility of the defective continuity of 1st electrode 31' decreasing in addition to the effectiveness of an example 1, and dependability improving.
[0057] (Deformation mode 2 of an example 2) Although piezo-electric plate 2' was divided into two partitions and two-electrodes 31' and 32' were allotted in the example 2, the deformation mode divided into three or more partitions may also be possible, and the method of division of a partition may also be concentric circular. for example, -- an elastic plate -- five -- ' -- a periphery -- the section -- ** -- fixing -- having -- **** -- a case -- **** -- being disc-like -- piezo-electricity -- a plate -- two -- ' -- inner circumference -- the section -- a periphery -- the section -- two -- a ** -- concentric circular -- dividing -- both -- a partition -- one side -- another side -- reverse -- applied voltage -- applying -- deformation -- a mode -- being possible . In this deformation mode, since it has reverse curvature in the inner circumference section and the periphery section, it is effective in both the generating force of an electrostrictive actuator and the maximum displacement becoming large.
[0058] [Example 3]
(The manufacture approach of an example 3) this invention -- an example -- three -- ****** -- an electrostrictive actuator -- one -- " -- drawing 11 -- being shown -- as -- an elastic plate -- five -- " -- one side (or both sides) -- joining -- having -- **** -- piezo-electricity -- a plate -- two -- " -- a front face -- a double helix -- a pattern -- drawing -- the -- one -- an electrode -- 31 -- " -- and -- the --

two -- an electrode -- 32 -- " -- forming -- having -- **** . Elastic plate 5" is disc-like sheet metal which consists of insulating ingredients, such as glass, and the slot of the thickness of this elastic plate 5" in which above-mentioned electrode 31" and 32" are mostly held over the whole is formed. the -- one -- an electrode -- 31 -- " -- the -- two -- an electrode -- 32 -- " -- very -- being narrow -- predetermined -- spacing -- vacating -- mutual -- adjoining -- forming -- having -- **** -- two electrodes -- 31 -- " -- 32 -- " -- an end -- respectively -- being disc-like -- piezo-electricity -- a plate -- two -- " -- a peripheral face -- predetermined -- area -- exposing -- **** .

[0059] the elastic plate 5 which adjoins the above-mentioned outcrop -- "the electrode pad P of an area predetermined to a front face" is formed by vacuum evaporationo thru/or a spatter, etc., respectively. this -- piezo-electricity -- a plate -- two -- " -- a peripheral face -- each -- an electrode -- 31 -- " -- 32 -- " -- an outcrop -- an electrode -- a pad -- P -- " -- conductive resin (or a conductive paste thru/or electroconductive glue) -- mutual -- flowing -- **** . The bonding wire thru/or lead wire which is not illustrated is connected to electrode pad P."

[0060] In addition, about the direction of polarization of the piezoelectric material of piezo-electric plate 2", it is the same as that of the above-mentioned example 1 and an example 2.

(The operation effectiveness of an example 3) since whole piezo-electric plate 3' acts by the piezoelectric constant d33 of piezoelectric material according to this example, while it can drive by the low battery -- the uni-morph and bimorph of the conventional technique -- comparing -- the generating force -- doubling -- max -- it is effective in a variation rate improving about several percent.

[0061] (The manufacture approach of an example 3) Electrostrictive actuator 1" of this example can be manufactured by enforcing the manufacture approaches, such as the deformation mode 1 of the manufacture approach of the above-mentioned example 1, and the deformation mode 2. The description of each manufacture approach and the difference in an advantage are the same as that of each deformation mode of the manufacture approach of an example 1.

(Deformation mode of an example 3) Also in this example, like an example 2, elastic plate 5" is formed with conductive spring spring materials, such as stainless steel, and each electrode 31" and the deformation mode in which 32" is formed by turns in the shape of [of a comb] a gear tooth from both sides of piezo-electric plate 2" are possible. a book -- deformation -- a mode -- if -- piezo-electricity -- a plate -- two -- " -- a rear face -- electroconductive glue -- conductivity -- an elastic plate -- five -- " -- joining -- having -- **** -- piezo-electricity -- a plate -- two -- " -- a front face -- the whole -- **** -- conductivity -- the film -- forming -- having -- **** . And elastic plate 5" and the conductive film have flowed with each electrode 31" and 32", respectively, and lead wire thru/or a bonding wire are connected to each of elastic plate 5" and the conductive film. So, electrode pad P" is unnecessary in this strange gestalt of the. Here, the conductive film can be formed by approaches, such as printing and baking of a conductive paste, vacuum evaporationo, CVD, and a spatter.

[0062] According to this strange gestalt of the, elastic plate 5" and the conductive film carry out each electrode 31" and an operation of whole 32" and the common electrode which has flowed, respectively. So, according to this strange gestalt of the, the circuit of a drive power source, electrode 31" and 32", and defective continuity of a between cannot happen easily, and since it is satisfactory even if 32" is disconnected on the way, there are electrode 31" and effectiveness that dependability improves, rather than an example 3.

[0063] In addition, this strange gestalt's of the electrostrictive actuator 1" can be manufactured by the manufacture approach of an example 2, and the same manufacture approach. Moreover, the alignment of each electrode 31" of the front flesh side of piezo-electric plate 2' and 32" is application of the ultra-fine processing technology of integrated circuits, such as LSI, and can be made [easy and] to a precision.

[Translation done.]

* NOTICES *

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damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The perspective view showing the configuration of the electrostrictive actuator as an example 1
[Drawing 2] The sectional view showing the configuration of the electrostrictive actuator as an example 1
[Drawing 3] The sectional view showing the direction of polarization and two electrodes of a piezo-electric plate of an example 1
[Drawing 4] The group Fig. showing an operation of the electrostrictive actuator as an example 1
(a) The sectional view showing the configuration in the condition that there is no applied voltage
(b) The sectional view showing the configuration in the condition that there is applied voltage
[Drawing 5] The perspective view showing connection of the lead wire to the electrostrictive actuator of an example 1
[Drawing 6] The mimetic diagram showing the slot formation process by laser beam machining
[Drawing 7] The mimetic diagram showing the slot formation process by reactive-ion-etching processing
[Drawing 8] The perspective view showing the configuration of the electrostrictive actuator as an example 2
[Drawing 9] The sectional view showing the configuration of the electrostrictive actuator as an example 2
[Drawing 10] The group Fig. showing an operation of the electrostrictive actuator as an example 2
(a) The sectional view showing the configuration in the condition that there is no applied voltage
(b) The sectional view showing the configuration in the condition that there is applied voltage partially
(c) The sectional view showing the configuration in the condition that there is applied voltage extensively
[Drawing 11] The perspective view showing the configuration of the electrostrictive actuator as an example 3

[Drawing 12] The perspective view showing the configuration of the piezo-electric uni-morph as a conventional technique
[Drawing 13] The group Fig. showing an operation of the piezo-electric uni-morph as a conventional technique
(a) The sectional view showing the configuration in the condition that there is no applied voltage
(b) The sectional view showing the configuration in the condition that there is applied voltage
[Description of Notations]
1, 1', 1'': Electrostrictive actuator
2, 2', 2'': Piezo-electric plate 2a, a 2a':slot
31, 31', and 31'': -- the 1st -- electrode 32, 32', and 32'': -- the 2nd electrode
41 and 41': -- common to the 1st -- electrode 42 and 42': -- the -- 2 common electrodes
5, 5', 5'': Elastic plate
6, 6':switch 7, 7': Drive power source (comparatively low battery) 8: Earth wire
9: Pure water 10: Infrared laser 11: Laser condensing optical system
12: Electrode substrate 13: Vacuum chamber 14: Magnetic field coil
15: RF generator 16: Evacuation system 17: Plasma
d31, d33: Piezoelectric constant L: Lead wire P, P': Electrode pad
P1: Piezo-electric uni-morph (conventional technique)
P2: Piezo-electric plate P3: Electrode P5: Disc-like elastic plate
P6: Switch P7: Drive power source (comparatively high voltage)

[Translation done.]